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Examination of Defects, Preventive Measures, and Remedies for Exhaust Manifolds in Foundries to Improve Overall Productivity

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Abstract - **Casting is one of the most widely used manufacturing processes for producing complex metal components. However, defects in cast components can significantly affect productivity, quality, and overall manufacturing costs. This study focuses on identifying common casting defects, analyzing their root causes, and implementing effective preventive measures and corrective actions to enhance the efficiency of foundry operations. Defects such as sand drop, blowhole, sand fusion, shift, and cold shut are examined using systematic quality tools, including Pareto analysis and Ishikawa diagrams. By optimizing process parameters such as pattern design, pouring temperature, and material composition, defect rates are reduced from 10.1% to 4.4%, leading to improved casting quality. Preventive measures, including proper mold preparation, controlled cooling rates, and effective raw material selection, are explored to minimize rejections and rework. Additionally, the study emphasizes the importance of real-time process monitoring and regular maintenance of equipment to sustain high-quality production. The findings demonstrate that structured defect analysis and proactive quality control measures significantly reduce scrap rates, lower production costs, and enhance foundry efficiency. This research provides valuable insights for foundries aiming to achieve higher productivity, reduce waste, and improve the reliability and performance of cast components.**
Keywords: **Casting Defects, Foundry Efficiency, Quality Control, Process Optimization, Preventive Measures**

I. INTRODUCTION

Metal casting is one of the primary manufacturing processes used to produce simple or complex products and is often the only method capable of producing large components in a single piece by pouring molten metal into a mold or die cavity and allowing it to solidify in the shape of the cavity. The identification of casting defects in the actual system is generally based on their visual appearance [1]. There are many types of castings. Sand casting is a metal casting technique that involves using sand to create a mold. In this process, molten metal is poured into a mold to form the desired shape. It is commonly used to produce metal items in various sizes and designs. In this project, various defects in casting components are analyzed using Pareto analysis. Root cause analysis of different defects is carried out using quality tools such as the Why-Why analysis and Ishikawa (fishbone) method. Corrective actions and preventive measures for each defect are implemented to cross-check and minimize defects, thereby improving overall productivity. The metal casting process is complex and involves several steps, including pattern making, mold and core preparation, melting and pouring, heat treatment, cleaning, and finishing. Each step involves multiple process variables [3]. Quality control tools play a crucial role in identifying defects and suggesting suitable solutions. These tools help determine the root causes of problems and aim to control them [4]. Casting defects are flaws that affect the quality of the final product and prevent it from meeting design or service requirements. Such defects can occur due to poor process control, material inconsistencies, or issues with casting equipment. Defects are generally categorized based on their causes and can be either surface or internal (bulk) defects. Metallurgical defects arise due to problems with alloy composition, melting temperature, poor mechanical properties, or internal stress. Common examples include porosity, shrinkage, inclusions, dross, and soldering. Thermal defects result from thermal stresses, improper fluid flow, or incorrect heat removal rates. Examples of thermal defects include hot tears, cold shuts, and thermal fatigue.

II. LITERATURE REVIEW

T. Elbel *et al.,*[1] discussed an expert system called ESWOD, developed at VSB-Technical University of Ostrava, to support casting defect analysis. This computer-based system used expert knowledge to identify and solve quality issues in castings. ESWOD comprised three main modules: defect identification, diagnosis of causes, and suggestions for prevention or remedies. The system primarily relied on visual inspection to identify defects and also helped analyse metallurgical, foundry, and other process-related causes. Such expert systems assist foundry professionals in improving casting quality and reducing rejection costs. Parlad Kumar *et al.,* [2] proposed a framework for developing Hybrid Investment Casting (HIC) for industrial applications. Their study analyzed process parameters and their impact on mechanical and metallurgical properties. Plastic patterns made using Fused Deposition Modeling (FDM) were successfully used for casting biomedical components. Investment casting is cost-effective for large-scale production, but rapid prototyping, such as FDM, offers practical solutions for small batch production. Combining FDM with traditional investment casting results in HIC, which can deliver customized properties for industrial and biomedical applications.

Wossenu Ali [3] investigated the causes of casting defects at the Kombolcha Textile Share Company foundry in Ethiopia. Common defects identified included blowholes, pinholes, and shrinkage. A fishbone (Ishikawa) diagram was used to identify major and minor process variables responsible for these defects. Experiments on molding sand and spectrometer analysis of defective parts revealed that high clay content (52.7%), poor gating design, incorrect pattern design, and uncontrolled pouring temperature were key factors. Trials with reclaimed sand and corrected gating and pattern designs successfully reduced defects.

Suyash Vichare *et al.,* [4] examined aluminium rim production at Neo Wheels industry, where frequent rework occurred due to casting defects. Pareto charts and Ishikawa diagrams were used to identify root causes and implement corrective actions. The study highlighted that using statistical quality control (SQC) tools significantly reduced rework and improved product quality.

Prateek Bhatt *et al.,*[5] analyzed casting defects in industrial trumpet housings. Total Quality Management (TQM) principles were applied to improve production. Pareto charts and Ishikawa diagrams were used to classify and analyze defects, which included improper sand properties, faulty gating systems, and operator errors. Corrective actions based on this analysis helped reduce defect rates and improve product quality.

Rahul T. Patil *et al.,* [6] examined common defects in aluminium-alloy die casting. Die casting, though fast and cost-effective, often produces defects. The study categorized defects based on root causes, providing useful insights for quality control teams to minimize rejections and enhance productivity.

Lukas Dwi Purnomo *et al.,*[7] optimized gating system design to improve radiator component production. Simulation results showed that a single-cavity design reduced cooling time and air entrapment, minimizing porosity-related defects and improving quality. Sandur Amar Waghambar *et al.,*[8] applied statistical quality tools and Auto-cast simulation to identify root causes of defects like sand drop, sand fusion, blow holes, and cold shuts. Corrective actions successfully reduced rejection rates.

Avinash Juriani [9] focused on critical casting defects and their root causes. The study emphasized achieving zero defect targets through systematic cause-and-effect analysis, helping foundries reduce rejections and improve yield.

Hardik Sheth *et al.,*[10] analyzed casting defects and implemented Lean Six Sigma approaches to reduce defects such as sand drop, blow hole, fin, rough surface, and cold shut. Feedback mechanisms between industries further improved quality.

Dr. D.N. Shivappa *et al.,* [11] studied Support Bracket (SB) castings at Dakshin Foundry Ltd, Bangalore, identifying defects like sand drop, blow hole, mismatch, and oversize. Corrective actions successfully reduced rejections and were incorporated into standard operating procedures Santosh S. Dabhole *et al.,*[12] reviewed die casting defects and their relation to process parameters. The study concluded that Six Sigma methods, process capability indices, and proper die casting parameters help minimize defects and improve productivity.

III. DATA COLLECTION FOR REJECTION ANALYSIS

A. Selection of Component

Deeps Ferrocast Pvt. Ltd manufactures approximately 85 casting components across multiple batches and shifts. Components with the highest rejection rates in December 2024 were selected for analysis. Ten components with the maximum rejections during this period were chosen, as tabulated in Table I.

TABLE I REJECTION PERCENTAGE OF 10 COMPONENTS WITH MAXIMUM REJECTION IN MONTH OF DECEMBER 2024

Sl. No	Item Name	Weight of each item	Qty of Casting per month	Rej Qty	Rej %
1	Exhaust Manifold	1.8	21200	2141	10.1
2	Valve housing	0.85	18450	1721	9.3
3	Transmission Housings	2.53	8562	567	6.6
4	Engine Brackets	1.32	10211	658	6.4
5	Valve 32	1.38	7545	452	6.0
6	Alternator Housing	0.62	8456	452	5.3
7	Oil Pump Casing	2.60	3540	146	4.1
8	Brake Calliper	0.8	2135	85	4.0
9	Turbocharger Housing	0.9	12000	452	3.8
10	Head Cover	1.10	5622	6184	233.2

Based on the Pareto analysis shown in figure 1, we observed that the Exhaust Manifold has the highest rejection percentage of 10.1%. Since it has the most significant impact on overall rejections, it has been chosen for detailed defect analysis to identify root causes and implement corrective actions.

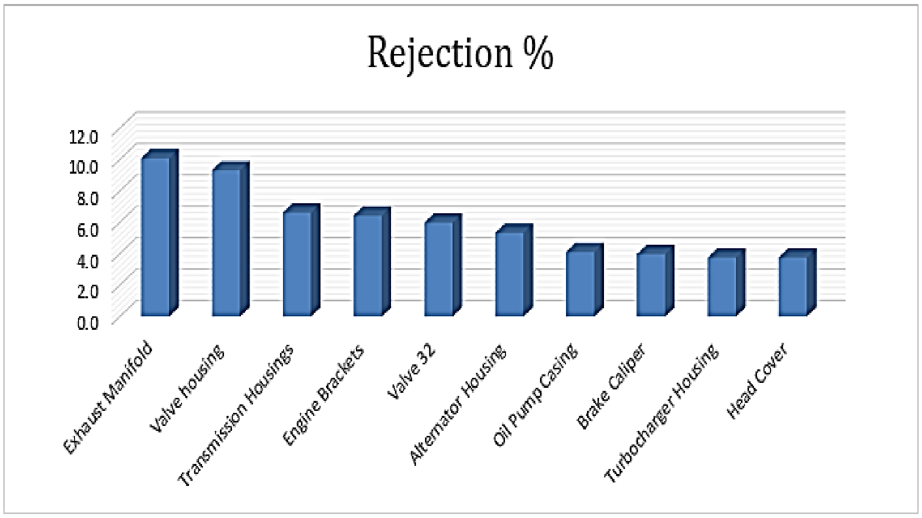

Fig. 1 Pareto analysis of Casting components

B. Defect Wise Analysis of Exhaust Manifold

The defects of Exhaust manifold are mentioned below. The details are in table II.

TABLE II DEFECT WISE ANALYSIS OF EXHAUST MANIFOLD

Defects	Rejection qty
Sand Drop	875
Blow hole	610
Sand Fusion	354
Shift	120
Cold shut	99
Mold damage	32
Excess Grinding	32
Sand swelling	19

The Pareto analysis in figure 2 highlights that defects such as sand drop, sand fusion, blow hole and shift contribute to a higher rejected quantity compared to others.

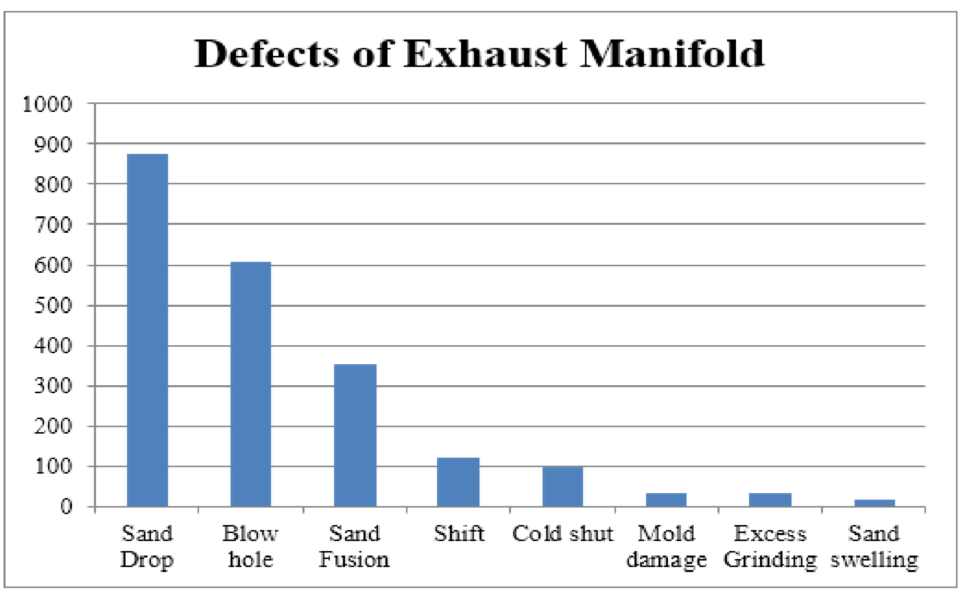

Fig. 2 Pareto Analysis Of Defects

C. Defect Analysis of Intake Manifold by Using Ishikawa Diagram

After gathering data on defects for the one month, the next step is to use quality tools to identify the root causes of these defects. The analysis in Pareto chart shows us four important defects they are as follows:

1. Sand drop,
2. Blow hole,
3. Sand fusion,
4. Shift

We will use following tools for root cause analysis

1. Ishikawa diagram
2. Why Why analysis

1. Sand Drop

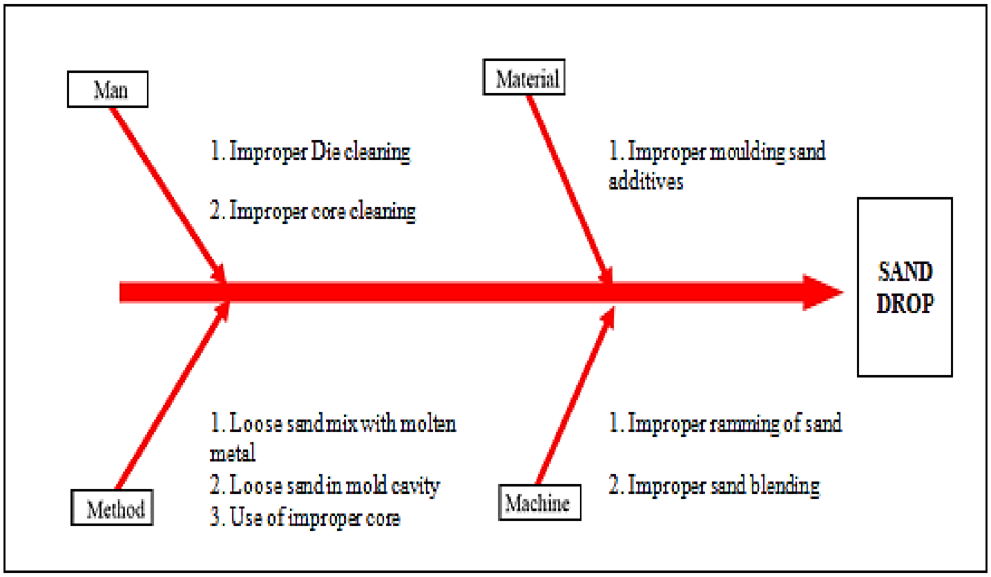

Fig. 3 Ishikawa diagram for sand drop defect

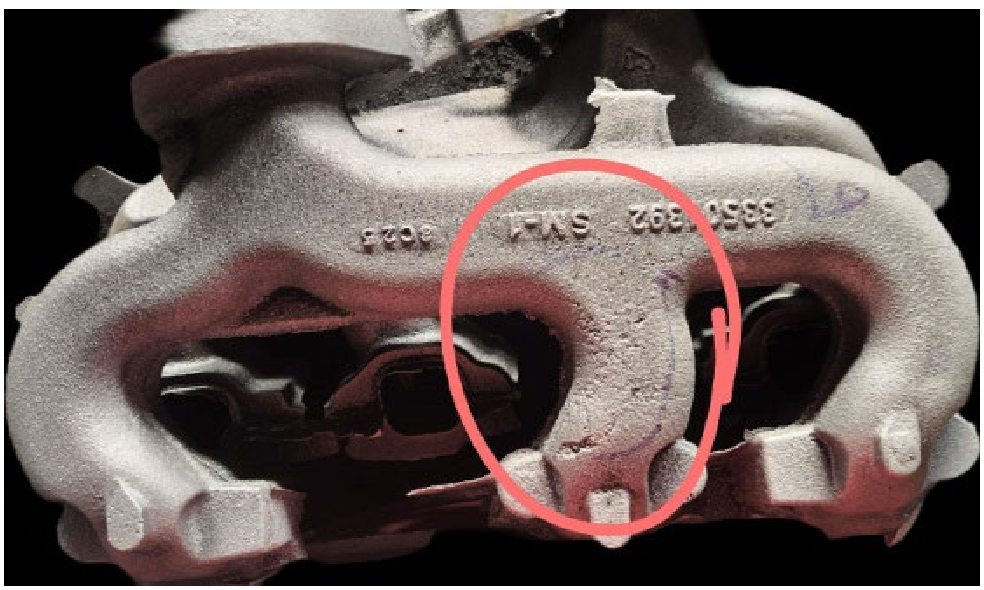

Fig. 4 Sand drop defect of Manifold

The initial observation using this tool indicates that loose sand is falling into the drag part of the mold cavity, resulting in a sand drop defect.

Figure 3 presents an Ishikawa diagram illustrating the potential causes of this defect. The primary issue identified is the binder, particularly bentonite, which contributes to the loose sand. To address this problem, the proportion of bentonite in the molding sand mixture should be reviewed and optimized. Additionally, Table III provides a detailed breakdown of each contributing factor along with recommended remedial actions to mitigate the defect.

TABLE III CAUSE, CONTRIBUTION, AND REMEDIAL ACTIONS FOR SAND DROP DEFECT IN CASTING

Cause	Contribution to Defect	Remedial Action
Insufficient binder content.	Weak sand bonding, resulting in loose sand falling into the mold cavity.	Optimize the proportion of binder (bentonite) in the moulding sand mixture.
Poor mold strength.	Weak sand mold structure, causing sand dislodgement.	Improve moulding sand composition to enhance compactibility.
Excessive moisture in sand.	Weakened sand particles, making them prone to dropping.	Maintain proper moisture content in the sand mixture.
Improper ramming or compaction.	Loose sand particles due to insufficient mold hardness.	Ensure uniform ramming for 5 seconds and adequate mold compaction.
Excessive sand fineness	Fine sand particles easily dislodged.	Use an appropriate sand grain size distribution.
Improper handling of molds.	Vibration and impact causing sand detachment.	Handle molds carefully during movement and assembly.
Low-quality or degraded sand	Weak mold structure leading to sand disintegration.	Use high-quality, well-maintained foundry sand.
Improper pattern design	Poor mold formation resulting in loose sand.	Modify pattern design to improve mold integrity.
High pouring velocity	Molten metal dislodging loose sand into the cavity.	Control the pouring speed to prevent sand erosion.
Lack of mold surface coating.	Loose sand particles detaching during metal pouring.	Apply mold coatings to strengthen surface integrity.

By implementing these corrective actions, the occurrence of sand drop defects can be minimized, leading to improved casting quality and reduced rejection rates.

2. Blow Hole:

Blowholes are defects formed when gas gets trapped in the molten metal and creates round or oval-shaped cavities as the metal solidifies. These are often linked to the presence of slag or oxides. Blowholes usually appear in the upper part of the Mold (cope), especially in areas with poor ventilation or in undercuts.

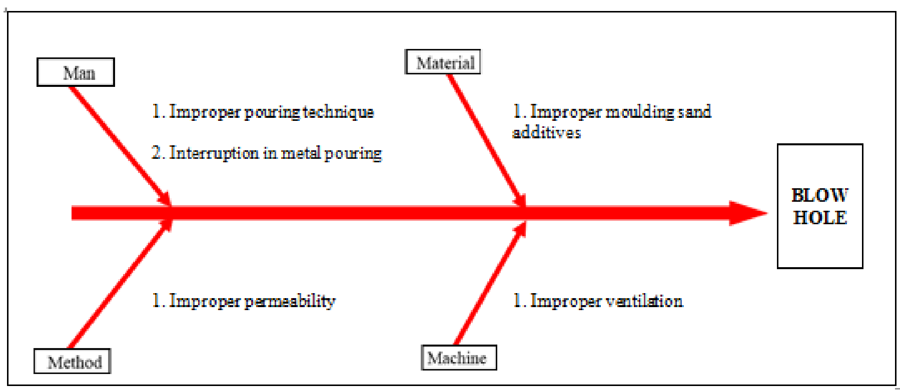

Fig.5 Ishikawa diagram for Blow hole defect

Fig.6 Blow hole defect in Manifold

Figure 5 illustrates the potential causes of the blowhole defect. Blowholes are caused by gas entrapment, primarily due to low permeability. Permeability refers to the ability of a material to allow gas to pass through it. Table IV presents the contribution of each cause along with the corresponding remedial actions. Cause, Contribution, and Remedial Actions for Blow Hole Defect in Casting

TABLE IV CAUSE, CONTRIBUTION, AND REMEDIAL ACTIONS FOR BLOW HOLE DEFECT IN CASTING

Cause	Contribution to Defect	Remedial Action
Low sand permeability	Trapped gases cannot escape, forming blow holes	Increase sand permeability by adjusting grain size and binder content
Excessive moisture in moulding sand	Generates excessive steam, leading to gas entrapment	Maintain optimal moisture content in sand mixture
Poor venting in Mold cavity	Trapped air and gases accumulate, forming defects	Improve venting by adding proper risers and vents
High binder content	Reduces sand permeability, preventing gas escape	Optimize binder proportion to balance strength and permeability
Improper gating system design	Restricts gas escape, increasing chances of blow holes	Design an efficient gating system with well-placed vents
Excessive metal pouring speed	Traps air and gases within the Mold cavity	Control pouring speed to allow gases to escape properly
Use of dirty or contaminated scrap metal	Increases gas content in molten metal	Use clean, degassed metal for casting
Improper Mold coating	Non-permeable coating traps gases inside	Use breathable coatings to allow gas escape
High pouring temperature	Increases gas solubility in molten metal, causing defects	Maintain optimal pouring temperature for the alloy
Core gas formation	Gases released from cores cause internal voids	Use low-gas-producing core binders and improve core venting

By implementing these corrective measures, blow hole defects can be significantly reduced, leading to better casting quality and lower rejection rates.

3. Sand Fusion

The figure 7 illustrates the potential causes of the sand fusion defect, where sand adheres to the metal.

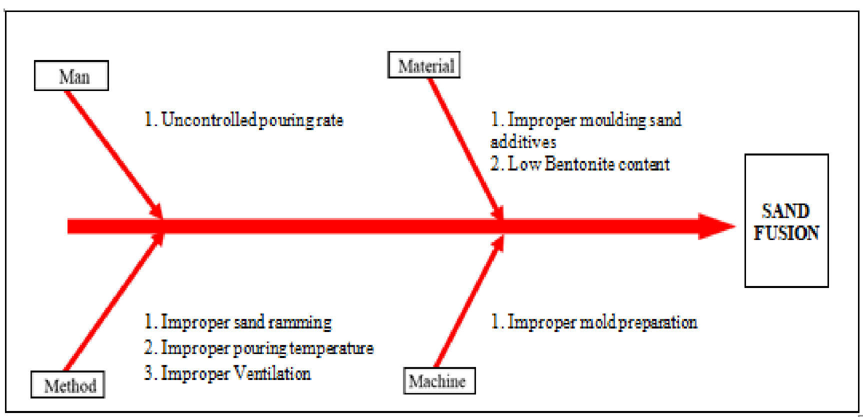

Fig.7 Ishikawa Diagram for Sand Fusion Defect

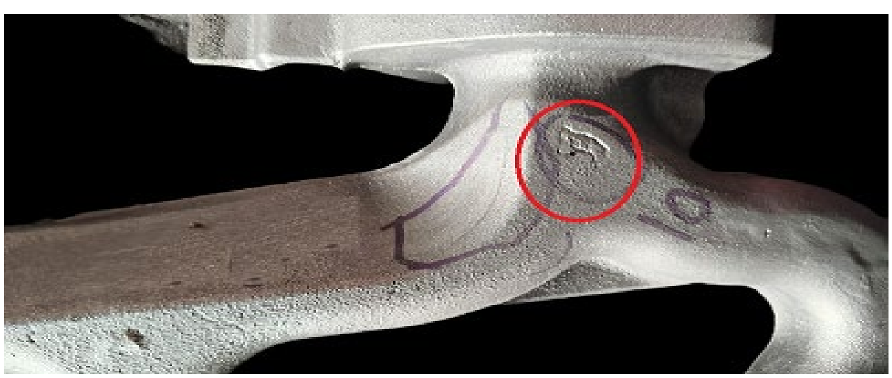

Fig.8 Ishikawa diagram for Sand fusion defect

The primary reasons for this defect are insufficient ramming and excessively high pouring temperature. This indicates that the pouring temperature should be reviewed, as detailed in table No. V below the Cause, Contribution, and Remedial Actions for Sand Fusion Defect.

TABLE V CAUSE, CONTRIBUTION, AND REMEDIAL ACTIONS FOR SAND FUSION DEFECT IN CASTING

Cause	Contribution to Defect	Remedial Actions
High pouring temperature	Causes excessive metal penetration into sand Mold	Optimize metal pouring temperature to recommended levels
Low refractory strength of sand	Leads to poor resistance against molten metal	Use high-quality sand with better refractoriness
Improper sand composition	Weakens sand Mold, making it prone to fusion	Maintain proper binder and additives ratio
Excessive metal fluidity	Increases likelihood of metal-sand fusion	Adjust alloy composition and pouring speed
Poor mold permeability	Traps gases, leading to sand fusion	Improve mold ventilation and permeability
Insufficient mold coating	Allows direct contact between metal and sand	Apply a suitable refractory mold coating
Use of fine sand grains	Reduces mold strength and increases sand fusion	Use coarser sand with appropriate grain size

By implementing these corrective measures, the occurrence of sand fusion defects can be significantly reduced, improving the overall casting quality and productivity.

4. Shift

The figure 9 illustrates the potential causes of the shift defect, which is a variation in the concentricity of all component diameters.

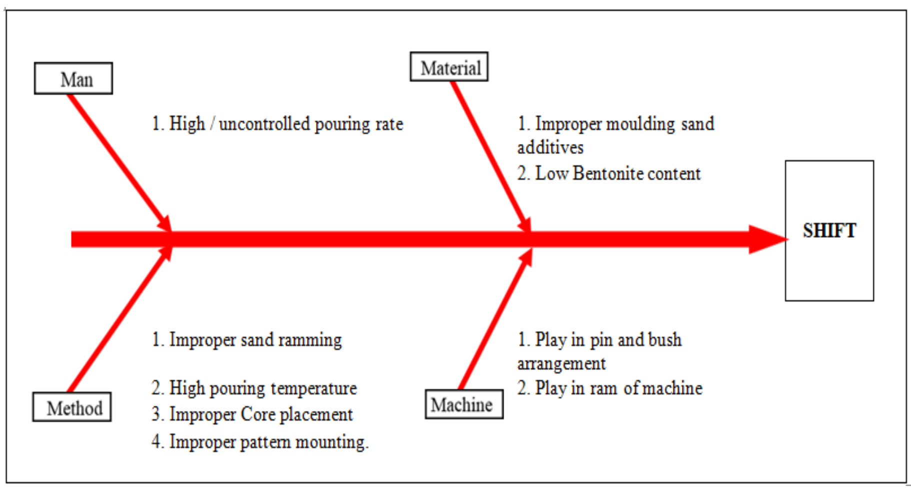

Fig.9 Ishikawa diagram for Shift defect in manifold

Fig.10 Shift defect in manifold

The parting line is perpendicular to the axis of the bush and pin used to align the two halves of the pattern. The Ishikawa diagram indicates an imbalance at the match plate. The Table VI provides a summary of the causes along with their remedial actions.

TABLE VI CAUSE, CONTRIBUTION, AND REMEDIAL ACTIONS FOR SAND FUSION DEFECT IN CASTING

Cause	Contribution to Defect	Remedial Actions
Improper alignment of mold halves	Causes mismatch between the top and bottom parts of the casting	Ensure proper alignment of the mold before pouring metal
Loose or damaged pattern	Leads to shifting of the mold cavity	Use well-maintained and accurate patterns
Weak or uneven clamping of mold	Allows movement of mold parts during pouring	Secure the mold firmly with even pressure
Excessive mold wear	Increases the chances of mold parts shifting	Replace worn-out molds regularly
Improper handling of the mold	Disturbs the mold position after setting	Handle molds carefully and avoid rough movements
High pouring velocity	Causes displacement of mold halves	Control the metal pouring speed properly
Vibration or external disturbances	Shakes the mold and shifts parts	Minimize vibrations near the molding area
Poor quality of core prints	Leads to improper placement of cores	Use precise core prints to maintain alignment
Insufficient draft angle	Causes pattern to drag the mold out of position	Ensure proper draft angle in the pattern

D. Corrective action

After applying the above remedial actions, the main concern was in the vents of the pattern. The design of the vents is improper in old pattern. Hence the vent was added at flanges of the manifold. They are shown in figure 11.

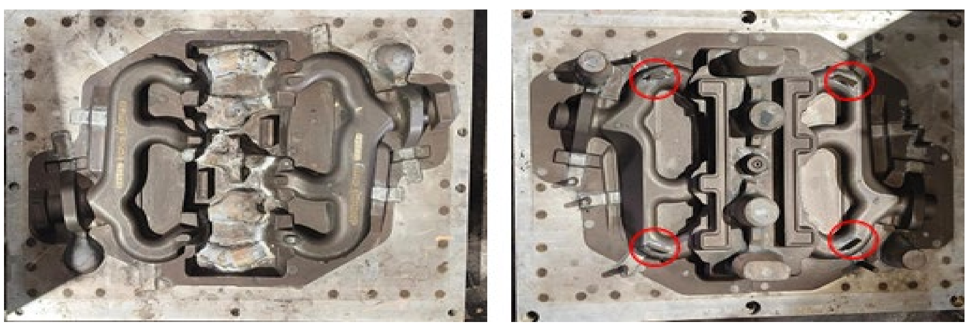

Fig.11 Corrections done in Pattern of manifold.

In month of January 2025, the total production of 19500 nos was done in which 864 nos were rejected. Total 1555 Kg pouring got rejected. After application of the remedies suggested and correction in pattern the rejection was reduced from 2141 to 864 qty. The rejection percentage is reduced by 10.1% to 4.4%. The details are shown in table VII.

TABLE VII DEFECT-WISE ANALYSIS OF EXHAUST MANIFOLD (JANUARY 2025)

Defects	Rejection
Sand Drop	388
Blow hole	154
Sand Fusion	187
Shift	68
Cold shut	42
Mold damage	5
Excess Grinding	8
Sand swelling	12

Sand drop defect was reduced from 875 to 388 nos. Blow hole defect is reduced from 610 nos to 154 nos. Sand fusion was reduced from 354 nos to 187 nos. Figure 12 shows Graphical representation of rejection qty in Exhaust Manifold.

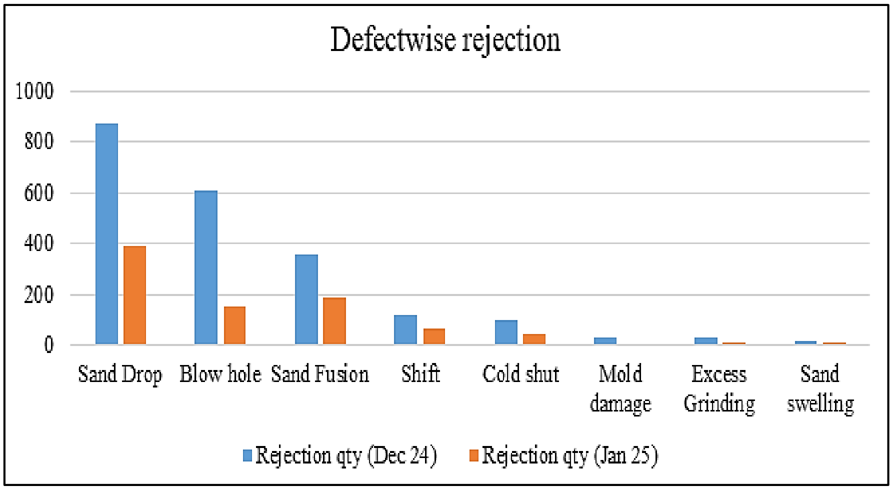

Fig.12 Graphical representation of rejection qty in Exhaust Manifold

IV. RESULTS AND DISCUSSION

A. Results

A detailed rejection analysis was carried out over a two-month period, during which the Ishikawa diagram (cause-and-effect analysis) was used as a quality tool to systematically identify the root causes of major casting defects. The key defects observed were sand drop, blow holes, and sand fusion. The implementation of corrective actions, identified using an Ishikawa diagram (fishbone analysis), led to a significant reduction in these defects. The figure 13 shows the reduction in the defect before and after application of remedial actions.

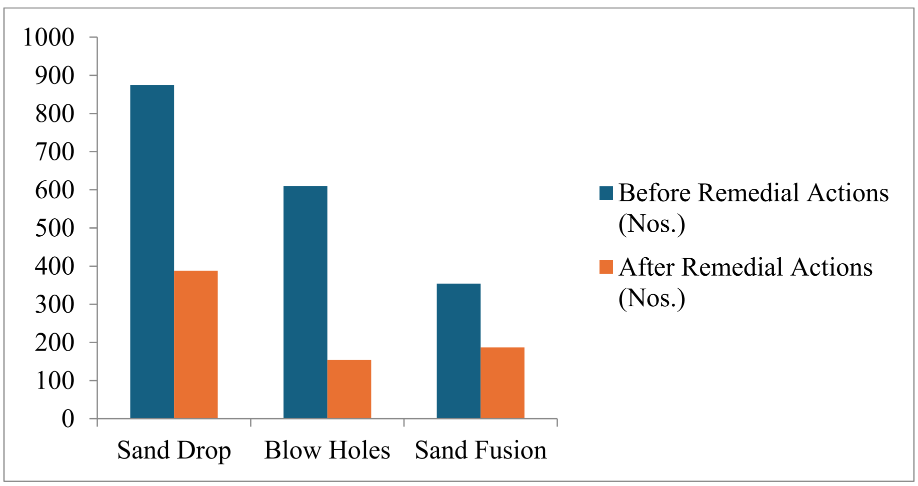

Fig.13 Rejection quantity in Exhaust Manifold before and after application of remedies

Prior to the intervention, the rejection rate of the exhaust manifold components stood at 10.1%. Post-remediation, this dropped to 4.4%, representing a statistically significant reduction of 56.4% in the rejection rate. The Defectwise reduction in rejection percentage is shown in Table No. VIII.

TABLE VIII PERCENTAGE REDUCTION IN DEFECTS

Defect Type	% Reduction
Sand Drop	55.60%
Blow Holes	74.80%
Sand Fusion	47.20%
Total Defects	60.40%

B. Discussion

The implemented improvements, particularly in pattern design (addition of vents), sand mixture quality, and temperature control, directly contributed to the decline in defect rates. Among the defects, blow holes showed the most substantial improvement, with a 74.8% reduction, indicating that better venting and gas escape paths in the mold were particularly effective. This aligns with general foundry literature, which identifies blow holes as primarily a result of poor gas evacuation.

The sand drop and sand fusion defects were mitigated through improvements in sand composition and mold handling processes. These defects are typically associated with mold strength and stability, further confirming that sand quality and binder proportions play a vital role.

V. CONCLUSION

The rejection analysis was conducted at The Deeps Ferrocast Pvt. Ltd for the component Exhaust Manifold. The Ishikawa diagram quality tool was utilized to identify the root causes of major defects. The component was studied and analyzed over a period of approximately two months. The following conclusions can be drawn from this study:

1. The pattern design was modified, and vents were added to the pattern, which effectively reduced defects. Additional remedies, such as optimizing the sand mixture and maintaining proper temperature, were also implemented, reducing overall defects from 10.1% to 4.4%.
2. The sand drop defect was reduced from 875 to 388 occurrences. The blow hole defect decreased from 610 to 154 occurrences, and sand fusion was reduced from 354 to 187 occurrences.

Overall, effective rejection control was achieved by analyzing the root causes and implementing appropriate remedial measures.

Declaration of Conflicting Interests
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Use of Artificial Intelligence (AI)-Assisted Technology for Manuscript Preparation
The authors confirm that no AI-assisted technologies were used in the preparation or writing of the manuscript, and no images were altered using AI.

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